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(54) COMMUTATION ARRANGEMENT FOR A DC MACHINE

(71) We, KABUSHIKI KAISHA MEIDENSHA, a Japanese Company of No. 2—1—17, Ohsaki, Shinagawa-ku, Tokyo, Japan, do hereby declare the invention for which we pray, that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a commutation arrangement for a DC machine and, more particularly, to an improvement of a commutator structure.

A commutator, which is fitted on a rotor shaft of a DC machine and connected to a rotor winding, is assembled so as to be in contact with a brush oppositely disposed with respect to the commutator itself.

A commutator has one important function which turns a DC machine into an electric motor by feeding DC power to a rotor winding through a brush, and another important function which turns a DC machine into a generator by taking out DC power generated in the rotor winding on rotation of a rotor shaft due to an AC power input.

The properties of a DC machine strongly depend on the commutator and it is therefore necessary to choose the composition of and manufacturing process for the commutator with due consideration of the mechanical and electrical properties of said commutator.

It is apparent that as commutation characteristics are directly influenced by wear and deformation of the commutator bar, it is necessary for this commutator bar to have considerable mechanical strength during operation. Moreover, in order to improve commutation characteristics, it is necessary to suppress a rise in temperature of the commutator bar which results from heat generated due to contact between said commutator bar and a brush or heat generated when an electric current flows in said commutator bar.

Therefore, it is desirable that the commutator bar is so disposed as to be well in contact with air for good dissipation of heat. A commutator is further required to be of light weight and to have good mechanical strength to be able to withstand bending stresses resulting from centrifugal forces during the rotation of the commutator. A commutator is still further required to provide with the shape having a suitable cross-sectional area which can accomodate heat therein.

With the above in view, a conventional commutation arrangement for a DC machine will be described.

A conventional commutation arrangement consists of a boss fitted on a rotor shaft, a plurality of commutator bars, each of which is provided with a dovetail portion at its bottom portion cylindrically disposed on the circumferential face of the boss through an insulating material, such as mica, and mechanically or electrically connected to a brush, and a riser portion for connecting the commutator bar to the rotor winding.

As aforementioned the temperature of a commutator bar will unavoidably rise in accordance with heat generated by mechanical and electrical loss generated while the commutator bar is in contact with a brush.

In a conventional commutator arrangement only the circumferential surface and both side surfaces in the direction of the axis of the commutator bar are exposed to air. Accordingly, any internal heat generated within the commutation arrangement cannot help but radiate through the boss, except for heat generated at faces exposed to air.

In view of these facts, it is proposed that providing ventilating bores in parallel with the axis of a rotor shaft in a boss in order to let the internal heat out of a commutation arrangement may bring about good cooling effects.

However, even if ventilating bores are provided in parallel with the axis of a rotor shaft in a boss, it has been difficult to obtain good cooling effects because of the difficulty in obtaining effective wind pressure sufficient to force air through the above ventilating bores which are long and narrow.

This results in a raising of the temperature of a commutator bar and thereby to a deterioration of the commutating action.

In view of the mechanical strength required of a commutator bar, it is necessary that the mechanical properties of said bar do not deteriorate even at a high temperature. However, such a commutator bar is costly to fabricate. Moreover, construction of a conventional commutation arrangement is complicated by the use of mica, which is inserted between boss and the commutator bar and between adjacent commutator bars.

It is, therefore, an important object of the present invention to provide a commutation arrangement for a DC machine which has good cooling effect by fabricating it so as to be well ventilated.

According to the present invention, therefore, there is provided a commutation arrangement for a DC machine which comprises

an elongate cylindrical rotor shaft,

a boss fitted on said rotor shaft, said boss having a plurality of radially projecting support portions spaced in the longitudinal direction of said shaft,

an insulating layer fitted on each outer circumferential surface of said support portion respectively, each of said insulating layers being a winding of a heat hardenable resin impregnated insulating tape,

a plurality of commutator bars extending in the longitudinal direction of said shaft, and spaced along the outer circumferential surface of each of said insulating layers, each commutator bar being mounted on said insulating layers in transverse relation thereto, and

a plurality of ventilating bores provided in said boss, whereby when said rotor shaft rotates, air is introduced from said ventilating bores to the space formed between adjacent commutator bars.

The feature and advantages of the commutation arrangements for a DC machine according to the present invention will become more apparent from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1A is a longitudinal cross-sectional view which schematically illustrates a preferred first embodiment of a commutation arrangement for a DC machine according to the present invention;

Fig. 1B is a side elevational view of a commutation arrangement for a DC machine of Fig. 1A;

Fig. 2A is a perspective view which shows schematically an example of a boss employed in a commutation arrangement for a DC machine according to the present invention;

Fig. 2B is a longitudinal cross-sectional view which schematically illustrates a construction including another boss employed in a commutation arrangement for a DC machine according to the present invention;

Fig. 3 is a longitudinal cross sectional view which schematically illustrates a construction including still another boss employed in a commutation arrangement for a DC machine according to the present invention;

Fig. 4A is a side view which schematically illustrates another modification of a commutator bar employed in a commutation arrangement for a DC machine according to the present invention;

Fig. 4B is a front view of a commutator bar of Fig. 4A;

Fig. 5 is a side view which schematically illustrates still another modification of a commutator bar employed in a commutation arrangement for a DC machine according to the present invention;

Fig. 6A is a side view which schematically illustrates connecting relation between a boss and a commutator bar employed in a commutation arrangement for a DC machine according to the present invention;

Fig. 6B is a perspective view of a commutator bar of Fig. 6A;

Fig. 7A is a longitudinal cross-sectional view which schematically illustrates another preferred embodiment of a commutation arrangement for a DC machine according to the present invention;

Fig. 7B is a side view of a commutation arrangement for a DC machine of Fig. 7A;

Fig. 8A is a longitudinal cross sectional view which schematically illustrates another modification of a wind guide plate employed in a commutation arrangement for a DC machine according to the present invention; and

Fig. 8B is a side view of a commutation arrangement for a DC machine of Fig. 8A.

As shown in Figs. 1A and 1B, a commutation arrangement for a DC machine is composed of an elongate cylindrical rotor shaft 10, a boss 12, which has a plurality of support portions 12*a*, 12*b* and 12*c* projected radially at a suitable interval as indicated by *d*, fitted on the rotor shaft 10 and a plurality of ventilating bores 16 which are circumferentially provided in the support portions 12*a*, 12*b* and 12*c* at a suitable distance in parallel with the axis of the boss 12. A plurality of insulating layers 18

are mounted on the outer circumferential surfaces 14 (see Fig. 1B) of the support portions 12*a*, 12*b* and 12*c* and a plurality of commutator bars 20, which are made of Cu or Cu alloy and are rectangular in cross section are disposed along the outer circumferential surfaces 14 in parallel with each other through the insulating material 18. Riser portions 22 for electrically connecting the commutator bars 20 to a rotor winding 24 are fitted on a rotor core 26. These portions 22 are integral with and bent at a suitable angle to (normally perpendicular) to the axis of the rotor shaft 10 (in Fig. 1A) and positioned at the extreme end portion 32 of the commutator bar 20.

The insulating layers 18 mounted on the support portions 12*a* and 12*c* have bent portions, as indicated by reference numeral 18*a*, which are bent radially inwardly as shown in Fig. 1A. A plurality of gaps, as indicated reference numeral 58, are formed between the commutator bars 20 which are disposed in parallel with each other on the circumferential face 14 of the supporting portions 12*a*, 12*b* and 12*c* as shown in Fig. 1B.

Fig. 2A illustrates an example of a boss 12 employed in the present invention. The boss 12 consists of a hollow cylindrical sleeve 12*d* and three disc-shaped support portions 12*a*, 12*b* and 12*c* fitted on the sleeve 12*d*, one of which is positioned on the midway portion of the sleeve 12*d* and the two remaining portions are positioned on each end of sleeve 12*d*, each support portion having a plurality of ventilating bores disposed equispaced circumferentially therein.

However, the construction of a boss 12 is not limited to the above example as shown in Fig. 2A. namely, it is also suitable to manufacture support portions by suitably machining the circumference of an elongated hollow cylindrical member.

Since annular hollow portions 30 between support portions 12*a*, 12*b* and 12*c* of the boss 12 and the commutator bars 20 are thus formed as shown in Fig. 1A, the inner circumferential surface of the commutator bars 20 as well as end surfaces thereof are exposed to air. Therefore, a good supply of air through the ventilating bores 16 are provided in the support portions of the boss 12 will bring about a great advance in cooling effect of the commutator bar 20. When rotor shaft 10 starts to revolve, in accordance with the centrifugal force of the rotor shaft 10, air, as indicated by an arrow 50 in Fig. 1A, is introduced through ventilating bores 16 and hollow portions 30 having contact with both sides of the commutator bars 20, and consequently heat generated in the commutator bars 20 is removed with high efficiency.

Fig. 2B illustrates a construction including another modification of boss 120, wherein the boss 120 consists of an annular cavity 40, which is formed by cutting the boss inwardly substantially in parallel with the axis of the rotor shaft 10. A plurality of supporting portions 120*a*, 120*b* and 120*c* project radially at suitable intervals and ventilating bores 116, are radially provided in the upper portion 120*u* of the boss 120, so that annular hollow portions 130 between the supporting portions 120*a*, 120*b* and 120*c* and the commutator bar 20 may be in fluid communication with the annular cavity 40 therethrough. A wind guide plate 60, is provided in the vicinity of the open end of the annular cavity 40.

When rotor shaft 10 starts to revolve, in accordance with the centrifugal force of the rotor shaft 10 air, as indicated by an arrow 52 in Fig. 2B is introduced through the annular cavity 40, ventilating bores 116 and the hollow portions 130 and thus has contact with both sides of the commutator bars 20. Consequently heat generated in the commutator bars 20 is efficiency removed.

Referring now to the insulating layer 18, this insulating layer 18 is constituted by winding semi-hard drawn and thermosetting insulating tape round the boss support portions till a predetermined thickness is obtained on the circumferential surface of the support portions 12*a*, 12*b* and 12*c*, giving a predetermined tension to the insulating tape. This insulating tape is made of semi-hard drawn material, which can be contracted and solidified by any suitable heat treatment; e.g. by the step of impregnating expoxy resin into a glass tape.

In order to introduce plenty of air into the hollow portions 30 in accordance with the rotation of the rotor shaft 10 as shown in Fig. 3, it is preferable to provide ventilating bores 216 in the support portions 12*a* and 12*c*, which are positioned at the both sides, of the boss 12 having a suitable outwardly slanting angle to the central axis of the rotor shaft 10. It will be expected with the above arrangement that air as indicated by an arrow 54 in Fig. 3 is introduced into the commutation arrangement at a high efficiency in accordance with the developed centrifugal force.

Figs. 4A and 4B illustrate another modification of a commutator bar 20, which is channel shaped, or inverse U shaped, in cross section. This is manufactured by means of bend processing or draw processing suitable material such as, Cu or Cu alloy having a desired mechanical strength. The bar of Fig. 4A is composed of an arcaute portion forming a commutation surface 70, which is provided with a plurality of ventilating bores 72, having suitable radius of curvature *R*, and a pair of

spaced radial leg portions 80 which are formed by bending the portions 70a and 70b of the arcuate portion 70 inwardly. Each leg portion 80 has a plurality of ventilating bores 74. Thus the acruate portion 70 integrally interconnects the upper ends of the spaced radial leg portions 80. In Fig. 4A, reference character θ indicates an angle formed between a pair of leg portions 80; and reference character h (= R — r) indicates height of the leg portion where r is a distance from the central point O of radius of curvature R to the lower ends 80a of the leg portions 80. As shown in Figs. 4A and 4B, slotted portions 82, which are formed for example, by a knurling process, are formed in parallel with the horizontral lines of the commutator bar 20 at the either side (at the outer side in Figs. 4A and 4B) of the lower ends of the leg portions to improve percolation and/or adhesive properties of fixing materials such as adhesives. Riser portion 22, which is illustrated in a condition which is not bent as yet in Fig. 4B, is formed integrally at the end of the commutation surface 70.

Another modification of a commutator bar 20, as shown in Fig. 5 includes a pair of inwardly projecting portions 84 which are provided integrally with the inner side of the lower end 80a of each of the leg portions 80 and which project toward each other. The pair of projecting portions 84 have substantially the same arcuate configuration as the arcuate portion 70.

With the commutator 20 as shown in Fig. 5, when the commutator 20 is fixed to the supporting portions 12a, 12b and 12c through the insulating layer 18, the pair of projections 84 of the leg portions 80 are secured firmly in the insulating layer 18. Accordingly, projections 84 allow the commutator bar 20 to be securely fixed to the support portions 12a, 12b and 12c.

Explanation of connecting the commutator bar 20 to the boss 12 will be described as follows:

A plurality of commutator bars 20 are circumferentially disposed on the support portions 12a, 12b and 12c of the boss through the insulating layer 18.

In order to connect the commutator bar 20 to the boss 12, commutator bar 20 is disposed on the support portions 12a, 12b and 12c of the boss 12 under a suitable radial pressure in the direction of the center of the boss 12 through the insulating tape in which resin is impregnated. The assembly is then heat treated at a predetermined curing temperature for a suitable period to cure the insulating tape.

The pressure applied to the insulating layer by the commutator bar 20 via the leg portions 80 causes the lower end 80a thereof as shown in Figure 6A to adhere to the insulating layer 18. Therefore, when the insulating layer 18 is cooled, commutator bar 20 is securely fixed to the support portions 12a, 12b and 12c of the boss 12 in accordance with the contraction and solidification of the resin.

When the commutator bar 20 is fixed to the boss 12 by heat treatment, because he slotted portions 82 are arranged longitudinally at the lower end 80a of the leg portions 80 the adhesive area between the lower end 80a of the leg portion 80 and the insulating layer 18 increases. Therefore, on contraction of the resin in the insulating tape when cooled the fixing stability of the commutator bar to the boss increases.

As seen in Figure 6B, the commutator bar 20 which is manufactured by bending plate of a material such as Cu or Cu alloy, has a cross sectional area, of an inverse U-shape permitting desired electric current to flow therethrough, and has a shape which is adopted to withstand centrifugal force generated during rotation thereof.

Therefore, the means for fixing the commutator bar to the boss can be of a less substantial construction than heretofore.

For this reason the weight of the commutator bar 20 and the fixing area being also reduced without imparing commutation performance. Moreover, when the commutator bar 20 is fixed to the boss 12, cavity 100, which is formed between the arcuate portion 70 and the pair of leg portions 80, allows an increase in the area which is in contact with air, and thereby enhances the cooling effect.

From the foregoing description concerning the first embodiment of the commutator arrangement for a DC machine according to the present invention, various advantages may be achieved as follows:

a. Because the commutator arrangement for a DC machine is provided with a boss 12, which has plurality of support portions projected radially at suitable intervals fitted on a rotor shaft, a plurality of ventilating bores 16 in the support portions, and a commutator bar 20 on the outer circumferential surface of the support portions, the ventilating effect can be remarkably improved and the inner surfaces of the commutator bar 20 will be effectively cooled. The weight of the boss 20 can also be reduced as compared to conventional designs and therefore the moment of inertia can be also reduced.

b. Because the commutator bar 20 is securely embedded to the boss 12 through the insulating layer 18 which is made of thermosetting material, it is unnecessary to use supplementary fixing elements such as dovetails or clamps and the step of fabricating a commutation arrangement can be facilitated. Moreover the bending

strength of the commutator bar 20 increases because the sectional rigidity thereof increases with respect to the weight thereof when a configuration as described above is utilized.

Furthermore, because each commutator bar 20 is isolated by an air space between adjacent commutator bars 20 the surface are of each commutator bar exposed to air increases and improvements in cooling effect can be easily obtained.

c. Because the commutator bar 20 is a channel or inverse U-shape in cross section and the cavity 100 is formed between commutation surface 70 having ventilating bores 72, and the pair of leg portions 80 having ventilating bores 74, the commutator bar 20 is well ventilated through the ventilating bores 72 and 74 and cavity 100, and therefore the ventilation effects will be improved as a result of an increase in area which is in contact with air.

Because the weight of the commutator bar 20 may be reduced as compared to the desired mechanical strength thereof, the resistance of the commutator bar 20 to deformation caused by centrifugal force on a rotation of rotor shaft 10 can be improved.

d. Because the commutator bar 20 is manufactured by bending a metal plate, such as Cu or Cu alloy, the commutator bar 20 is easy to manufacture and production costs as well as the quantity of materials required for the commutator bar 20 can also be reduced.

e. Because the riser portion 22 is integrally formed with the commutator bar 20, the strength thereof increases and the number of manufacturing steps can be commensurately reduced.

f. Because of the reduction in weight of the boss 12 and the commutator bar 20, the moment of inertia of the commutation arrangement is reduced and consequently, the inertia moment of the rotary electrical machine which contains the commutator bar therein can be also reduced. This improves the ease of starting and stopping of such a rotary electrical machine and consequently the electrical power requirements thereof can be reduced.

g. Because of the improvement in ventilation and cooling of the commutator bar, changes in dimension thereof due to rises in temperature thereof can be reduced. This stress caused by such changes in dimension can be easily absorbed by the insulating layer in which the leg portions of the commutator bar 20 are embedded, and the life of the commutation arrangement will be increased.

A second embodiment of a commutation arrangement for a DC machine according to the present invention is similar in outline to the first embodiment described above, but in this second embodiment a wind guide plate is provided in the vicinity of the ventilating bores of the supporting portions of the boss.

Figs. 7A and 7B illustrate a preferred second embodiment according to the present invention and Figs. 8A and 8B illustrate another modification of a wind guide plate as shown in Figs. 7A and 7B.

In Figs. 7A, 7B, 8A and 8B, the same reference numerals as used in Fig. 1 to Fig. 6 indicate corresponding (equivalent) elements of the commutation arrangement for a DC machine and therefore, detailed description of the corresponding elements described above will be omitted.

As shown in Figs. 7A and 7B, wind guide plates 90 are provided in the vicinity of the ventilating bores 216, which slant toward the axis of the rotor shaft 10 so that air is easily drawn through the ventilating bores 216, provided in the support portions 12*a* and 12*c* which are positioned at the both ends of the boss 20 and projected radially. As best shown in Fig. 7*b*, wind guide plates 90 are disposed equiangularly on the end surface 114, which correspond to the outer sides of the supporting portions 12*a* and 12*c*, in a circular array so that each plate 90 is positioned near a corresponding ventilating bore 216. When the rotor shaft 10 starts to revolve, owing to the wind guide plates 90 preventing flow of wind which is unfavorable to ventilation, air as indicated by an arrow 54 in Fig. 7A is drawn into the ventilating bores 216 at a high efficiency.

Figs. 8A and 8B illustrate another modification of a wind guide plate, wherein each L shaped wind guide plate, as indicated by reference numeral 92, is composed of a flat portion 92*a* and bent portion 92*b* bent normally to the flat portion 92*a*, and is disposed equiangularly on the end surface 114 in a circular array so that each plate 92 is positioned near a corresponding ventilating bore 216. When the rotor shaft 10 starts to revolve wind which is unfavorable to ventilation is prevented by the inner bent surface of the wind guide plate 92 and thereby is turned into desirable wind pressure, and air is forcedly drawn into the ventilating bores 216.

From the foregoing description, it will now be appreciated that the following advantages as well as ones stated in the first embodiment can be achieved in the commutation arrangement for a DC machine according to the present invention as follows;

Because wind guide plates 90 or 92 are disposed equiangularly on the end surfaces 114, which correspond to the outer sides of the support portions 12*a* and 12*b*, in a circular array so that each plate 90 or 92 is positioned near corresponding ventilating

bores 216, when the rotor shaft 10 starts to revolve, air can be forcedly drawn into the boss 12 through the ventilating bores 216 by a desirable wind pressure generated in the vicinity of the ventilating bores 216 in accordance with the rotation of the shaft 10, and thereby high cooling effects can be easily obtained.

WHAT WE CLAIM IS:—

1. A commutation arrangement for a DC machine which comprises

an elongate cylindrical rotor shaft,

a boss fitted on said rotor shaft, said boss having a plurality of radially projecting support portions spaced in the longitudinal direction of said shaft,

an insulating layer fitted on each outer circumferential surface of said support portions respectively, each of said insulating layers being a winding of a heat hardenable resin impregnated insulating tape,

a plurality of commutator bars extending in the longitudinal direction of said shaft, and spaced along the outer circumferential surface of each of said insulating layers, each commutator bar being mounted on said insulating layers in transverse relation thereto, and

a plurality of ventilating bores provided in said boss, whereby when said rotor shaft rotates, air is introduced from said ventilating bores to the space formed between adjacent commutator bars.

2. A commutation arrangement for a DC machine as defined in claim 1, wherein each of said commutator bars is rectangular in cross section.

3. A commutation arrangement for a DC machine as defined in claim 1, wherein each of said commutator bars is channel shaped or an inverse U-shape in cross-section.

4. A commutation arrangement for a DC machine as defined in any one of claims 2 and 3, wherein said boss consists of a hollow cylindrical sleeve and at least two disc-shaped support portions, which are positioned and fitted on each end of said sleeve.

5. A commutation arrangement for a DC machine as defined in any one of claims 1 to 4, which further comprises riser portions each of which is formed integrally on each of said commutator bars.

6. A commutation arrangement for a DC machine as defined in any one of claims 1 to 5, wherein each of said support portions is provided with a plurality of ventilating bores.

7. A commutation arrangement for a DC machine as defined in claim 6, wherein said support portions positioned at the both ends of said boss are provided with a plurality of ventilating bores each of which is slanted towards the axis of said shaft.

8. A commutation arrangement for a DC machine as defined in any one of claims 1 to 7, wherein each of said commutator bars is provided with a plurality of ventilating bores therein.

9. A commutation arrangement for a DC machine as defined in claim 3, wherein said commutator bar comprises a pair of spaced radial leg portions and an arcuate portion integrally interconnecting the upper ends of said spaced radial leg portions of said pair, said arcuate portion including a commutation surface.

10. A commutation arrangement for a DC machine as defined in claim 9, which further comprises a slotted portion formed in a surface of the lower end of each of said leg portions.

11. A commutation arrangement for a DC machine as defined in claim 10, which further comprises a pair of projecting portions each of which is integrally formed in the inner side of the lower end of the leg portions and are projected toward each other, said projecting portions being substantially as arcuate as said arcuate portion.

12. A commutation arrangement for a DC machine as defined in claim 11, wherein at least one of said leg portions and said arcuate portion including said commutation surface is provided with a ventilating bore.

13. A commutation arrangement for a DC machine as defined in any one of claims 1 to 12, wherein a lower end of each of said commutator bars is embedded in said insulating layer.

14. A commutation arrangement for a DC machine as defined in any one of claims 2 to 3, wherein said boss is further provided in the axial direction thereof with an annular cavity therein, said cavity having an open end and a plurality of ventilating bores, each of which is radially provided in the upper portion of said boss in such a manner that the space formed between said supporting portions and said commutator bar is in fluid communication with said annular cavity therethrough.

15. A commutation arrangement for a DC machine as defined in claim 14, which is further provided with a wind guide plate in the vicinity of the open end of said annular cavity.

16. A commutation arrangement for a DC machine as defined in claim 7, wherein a plurality of wind guide plates are provided in the vicinity of the ventilating bores which slant toward the axis of said rotor shaft in such a manner that they are disposed equiangularly on the end surfaces corresponding to the outer sides of said supporting portions positioned on both ends thereof.

17. A commutation arrangement for a DC

machine as defined in claim 16, wherein each of said guide plates is L shaped in cross section.

18. A commutation arrangement for a DC machine hereinbefore described and shown in Figs. 1A and 1B and Figs. 2B to 8B of the accompanying drawings.

19. A commutation arrangement for a DC machine hereinbefore described and shown in Figs. 1A and 1B as modified by Figs. 2A of the accompanying drawings.

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Fig. 1A

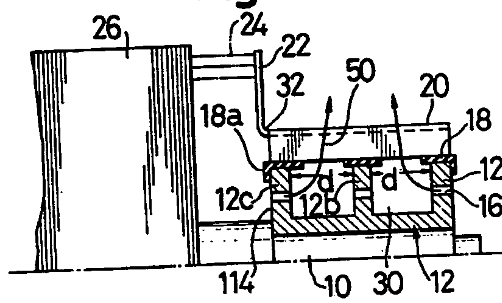


Fig. 1B

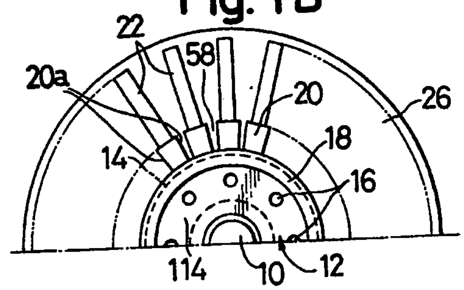


Fig. 2A

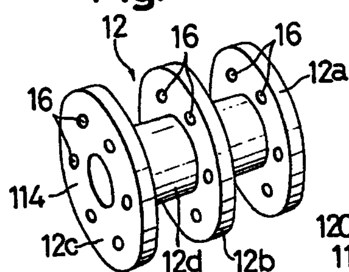
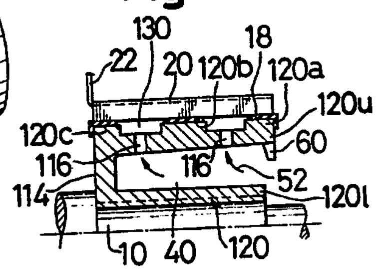


Fig. 2B



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Sheet 2

Fig. 4A

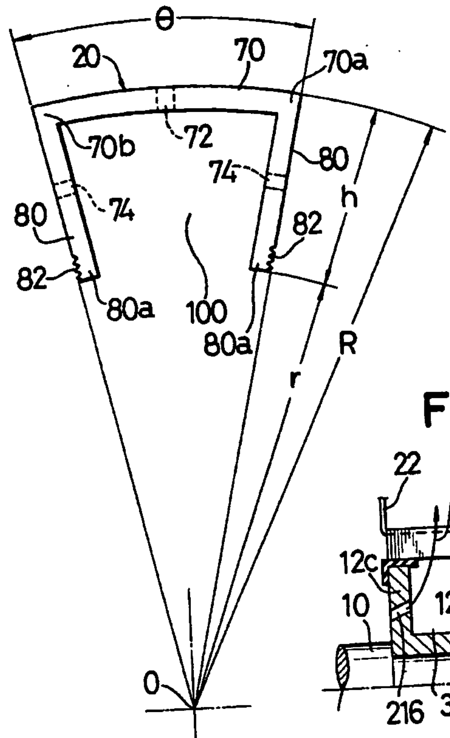


Fig. 3

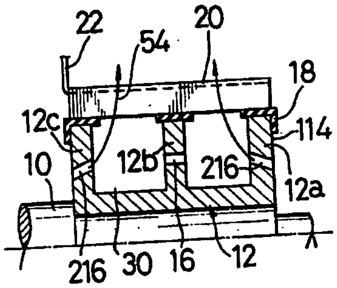
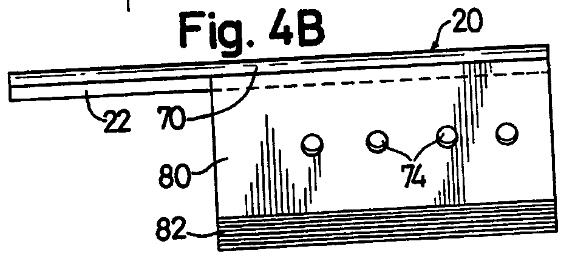


Fig. 4B



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Sheet 3

Fig. 5

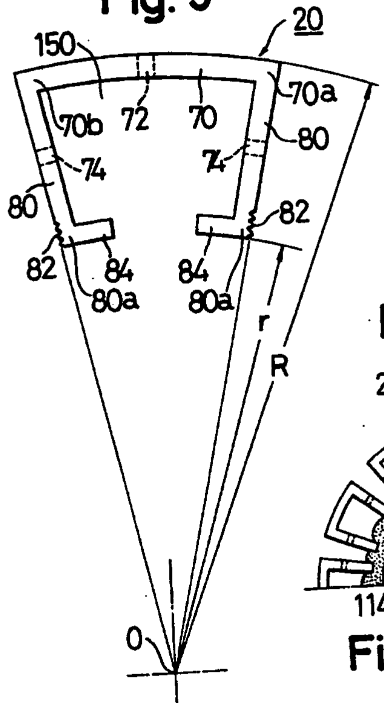


Fig. 6A

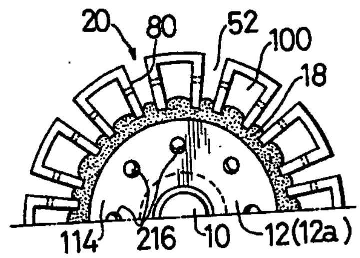


Fig. 6B

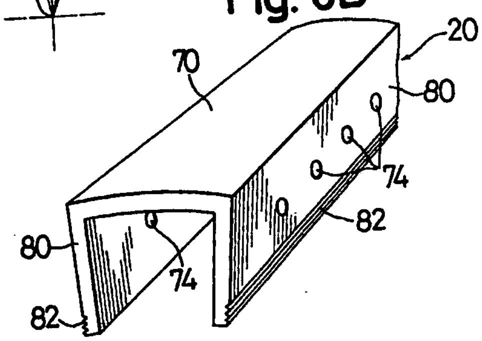
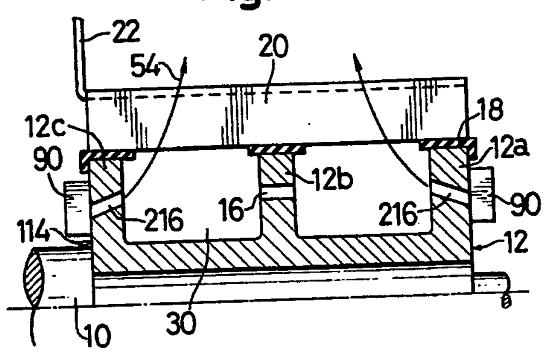


Fig. 7A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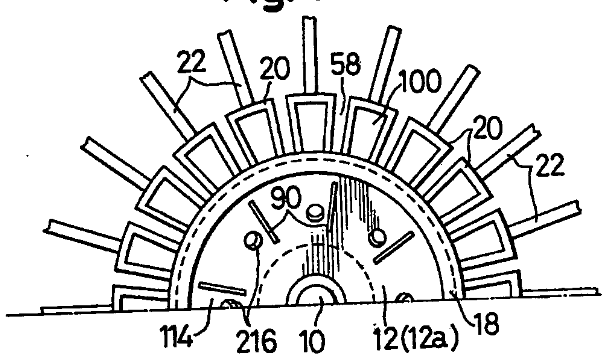
10

Fig. 7B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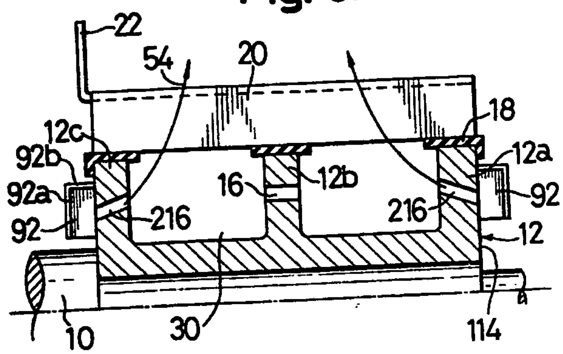
10
12(12a)
18

Fig. 8A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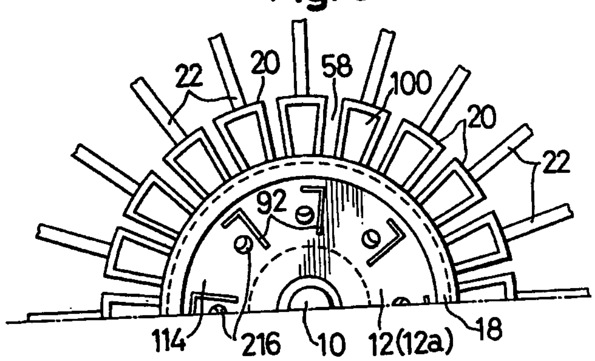
92b
92a
92
12a
12b
16
216
216
92
12
10
30
114

Fig. 8B


22
20
58
100
20
22
92
114
216
10
12(12a)
18